Long-term field experiment for monitoring soil carbon content in Japanese grasslands: initial data from 2010 to 2012

Shoji Matsuura [A], Hiroshi Hibino [B], Reiko Kazama [B], Hiroyuki Sasaki [A] and Masayuki Hojito [C]

[A] National Agriculture and Food Research Organization Institute of Livestock and Grassland Science, 768 Senbonmatsu, Nasushiobara, Japan, http://www.naro.affrc.go.jp/nilgs/
[B] National Livestock Breeding Center, 1 Odakurahara, Odakura, Nishigo, Nishishirakawa, Japan, http://www.nlbc.go.jp/
[C] Kitasato University School of Veterinary Medicine, 23-35-1 Higashi, Towada, Japan, http://www.kitasato-u.ac.jp/vmas/

Contact email: shojim@affrc.go.jp

Abstract. A long-term field experiment for monitoring soil carbon content in Japanese grasslands started in 2010 to investigate the changes in soil carbon content and the effect of composted livestock manure application. We established grassland plots with 3 levels of manure application treatment at 10 sites. Bulk density values in many sites had wide inter-replicate and inter-annual variability. It is reasonable to suppose that the variability in the bulk density reflect spatial variability of physical properties within the grasslands because the annual trends of the bulk density values were not consistent. Organic carbon concentration tended to increase yearly in the surface layer (0–5 cm), whereas those for the subsoil layer (5–30 cm) stayed relatively constant. The organic carbon concentration in the surface layer tended to increase with increasing latitude and the amount of manure applied. When data from all the sites were taken into account, carbon content also tended to increase over time following grassland renovation. These results indicate that Japanese grasslands have the potential to sequester organic carbon. The monitoring has just begun, and it is important to continue the effort to achieve the goals of this study.

Keywords: Soil carbon stock, cultivated grassland, manure application, national soil survey.

Introduction

Soil is the largest pool of organic carbon in all types of terrestrial ecosystems (Batjes 1996), which include forests, grasslands and agroecosystems. Thus, soil has a huge potential for either sequestering or releasing carbon into the atmosphere (Kutsch *et al.* 2009). With the current increase in atmospheric carbon dioxide, it has high priority to evaluate the feasibility of managing ecosystems for carbon sequestration.

Grasslands play a significant role in global carbon storage due to high levels of carbon accrual and sequestration below ground (Gibson 2009). Grassland soil carbon can be increased with the implementation of improved management practices (Conant *et al*. 2001), such as nitrogen fertilization, manure application and grazing.

As part of the framework for the Post Kyoto Protocol, the need for estimating carbon stock changes associated with grazing land management as well as other activities (forest management, cropland management and revegetation) is expected to grow. In Japan, however, relatively little is known about changes in carbon stocks in grassland soils, partly because information on grassland soils had not been collected systematically in the past. To investigate the changes in soil carbon content and the effect of livestock manure application, a long-term field experiment for monitoring soil carbon content in grasslands started in 2010 under the auspices of a national monitoring program, "Greenhouse gas emission from soils and carbon content in arable land in Japan".

This paper summarizes these results using data collected during the first three years (2010 to 2012).

Methods

Field experiments were conducted at 10 sites across Japan: 9 stations at the National Livestock Breeding Center (NLBC), and 1 at the National Agriculture and Food Research Organization Institute of Livestock and Grassland Science (NILGS), Nasu Research Station (Fig. 1).

Figure 1. Location of the monitoring sites.

Table 1. Annual variations in bulk density and mass percent of gravel (>2 mm) content for the 1st layer (0–5 cm). Values represent means and standard deviations (n = 3). Treatment without manure application (0 Mg/ha/y) in all sites.

Monitoring site	Bulk density (Mg/m^3)			Gravel content rate (%)		
	2010	2011	2012	2010	2011	2012
Tokachi	0.40 (0.02)	0.45 (0.04)	0.39 (0.01)	2.3 (1.8)	3.1 (2.8)	2.9 (2.3)
Niikappu	0.58 (0.03)	0.47 (0.02)	0.56 (0.06)	2.7 (0.2)	0.3 (0.2)	0.1 (0.1)
Ohu	0.64 (0.04)	0.71 (0.03)	0.72 (0.03)	1.5 (0.4)	0.5 (0.2)	0.4 (0.2)
Iwate	0.64 (0.12)	0.78 (0.14)	0.82 (0.13)	17.0 (3.6)	5.0 (1.7)	5.3 (1.2)
Nishigo	0.68 (0.02)	0.66 (0.04)	0.54 (0.03)	2.6 (1.4)	1.7 (1.3)	5.1 (0.7)
Nasu	0.96 (0.08)	1.06 (0.12)	0.94 (0.06)	2.8 (2.3)	2.3 (0.8)	1.4 (1.1)
Nagano	1.06 (0.03)	0.95 (0.11)	0.99 (0.05)	4.0 (0.8)	2.4 (0.4)	4.1 (2.5)
Tottori	0.84 (0.06)	0.87 (0.05)	0.83 (0.04)	8.4 (2.4)	6.5 (2.0)	1.9 (0.7)
Kumamoto	0.63 (0.08)	0.99 (0.09)	0.61 (0.06)	46.7 (6.8)	14.0 (1.4)	13.7 (0.5)
Miyazaki	0.67 (0.10)	0.74 (0.12)	0.71 (0.10)	0.0 (0.0)	0.1 (0.2)	3.3 (0.8)

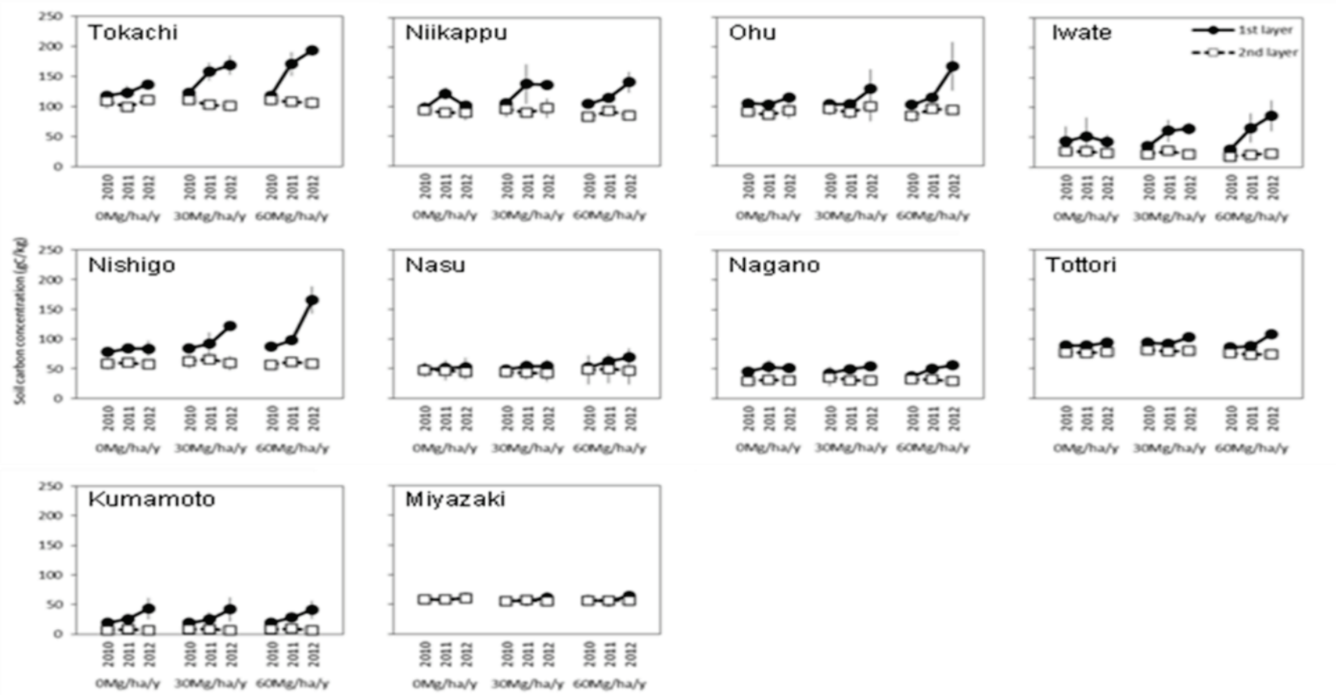

Figure 2. Inter-annual variations in soil carbon concentration of each treatment. Values represent means and standard deviations (n = 3)

Nine grassland plots were established at each site in 2010. The plots received 3 levels of treatment (0 Mg/ha/y, 30 Mg/ha/y and 60 Mg/ha/y of composted livestock manure application rate) × 3 replications per treatment. The grasslands are categorized as cultivated grassland (Allen *et al*. 2011), where no animals were grazed and grasses were cut 2–4 times per year. Manure was applied annually after the final cut (late autumn to winter).

Soils of each plot were collected yearly to a depth of 30 cm before manure application. Core samples and bulk samples were taken from two layers (0–5 cm and 5–30 cm) to determine bulk density and organic carbon concentration. The bulk density was determined as the mass of soil excluding coarse fragments >2mm divided by the sample volume. The organic carbon concentration was determined by dry combustion method. The soil organic carbon content per unit area was calculated for each layer by multiplying the bulk density, the organic carbon concentration and the thickness of soil layer. The first soil samples were taken just before the first manure application; accordingly, soil data in 2010 (starting values) were not affected by manure application.

Results and discussion

Bulk density values in many sites had wide inter-replicate variability (Table 1). They also had wide inter-annual variability, but the trends were not consistent. It is reasonable to suppose that the variations in bulk density values reflect spatial variability of physical properties within the grasslands. Mass percent of gravel content in most sites also had wide inter-replicate and inter-annual variability (Table 1). Gravel content rate is likely to be one of the main factors which causes the variability in bulk density because it affects the bulk density values determined in this study.

In many plots, organic carbon concentration values for the 1st lay (0-5 cm) layer tended to increase each year,

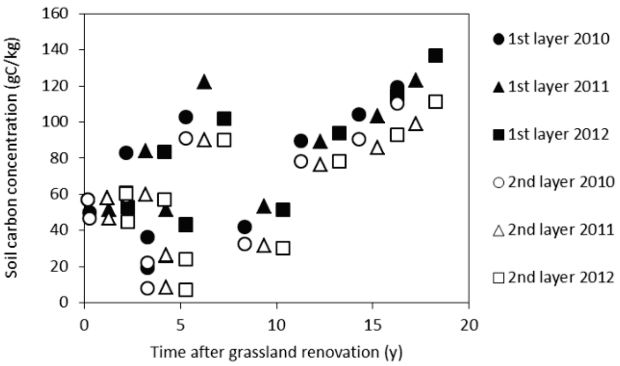

Figure 3. Relationship between the time after grassland renovation and soil carbon concentration in each layer. Treatment without manure application (0 Mg/ha/y) in all sites

whereas those for the 2nd (5-30 cm) layer stayed relatively constant (Fig. 2). The organic carbon concentration for the 1st layer tended to increase with increasing latitude and the amount of manure applied. The increase in organic carbon concentration in the manure-applied plots in the high-latitude site can be explained by reduced manure decomposition rate due to low temperature. In contrast, there was no clear increase or effect of manure application in organic carbon content per unit area, even within the 1st layer. We can confidently state that the main reason for this is variability in the bulk density values.

When data from all the sites are considered, soil organic carbon concentration tended to increase over time after grassland renovation (plowing and resowing), even within the 2nd layer (Fig. 3). This result indicates that Japanese grasslands have the potential to sequester organic carbon. However, it must be noted that the effect of environmental conditions (climatic and/or soil conditions) must be considered.

The monitoring program has just begun, and it is important to continue this survey to elucidate the changes in carbon content in Japanese grassland soils and the effects of livestock manure application and/or environmental conditions.

Conclusion

In 2010, we began monitoring soil carbon content at 10 grassland sites in Japan to investigate the changes in soil carbon content and the effect of livestock manure application. Organic carbon concentration tended to increase yearly in the surface layer (0–5 cm), with increasing content correlated with increasing latitude and the amount of manure applied. When data from all the sites were taken into account, carbon content also tended to increase over time following grassland renovation. The monitoring program is new, and it is important to continue the effort to achieve the goals of this study.

Acknowledgements

We wish to thank the staff of the NLBC and the NILGS for their assistance in collecting and processing of the soil samples. This study was supported by the national monitoring survey program “Greenhouse gas emission from soils and carbon content in arable land in Japan”.

References

Allen VG, Batello C, Berretta EJ, Hodgson J, Kothmann M, Li X, Mclvor J, Milne J, Morris C, Peeters A, Sanderson M (2011) An international terminology for grazing lands and grazing animals. *Grass and Forage Science* **66**, 2-28.

Batjes NH (1996) Total carbon and nitrogen in the soils of the world. *European Journal of Soil Science* **47**, 151-163.

Conant RT, Paustian K, Elliott ET (2001) Grassland management and conversion into grassland: effect on soil carbon. *Ecological Applications* **11**, 343-355.

Gibson DJ (2009) ‘Grasses and grassland ecology’ (Oxford University Press: New York)

Kutsch WL, Bahn M, Heinemeyer A (2009) Soil carbon relations: an overview. In ‘Soil carbon dynamics’ (Eds WL Kutsch, M Bahn, A Heinemeyer) pp. 1-15. (Cambridge University Press: New York)